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Canonical correlation between musical and cognitive abilities of dancers

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1. Introduction

When talking about activities in the sphere of musical art it should be mentioned that they are, as just like all other human activities, conditioned by the abilities of people who are occupied with them. The ability of people to notice, comprehend, and reproduce rhythmic, melodic and harmonic elements of music, which is classified as musicality, depends primarily on the role of cognitive personality factors. It may be supposed that cognitive factors will influence the success in musical activities, but it seems that the influence of a spatial factor would be the most significant. Spacialization is defined as the ability to determine relations in a space or to solve many problems considered as spatial problems.

Nevertheless, other cognitive factors are certainly important for every aspect of musical activity. However, cognitive factors are not the only ones that are crucial for the success in some activity, including musical activities. In this work, the relations between musicality and cognitive abilities will be researched.

2. The research methods

2. 1. The sample of examinees

The sample of examinees is conditioned by the financial capabilities necessary of the research procedure. Besides, the sample depends on the number of qualified and trained measurers, on the instruments and standardized conditions in which the planned research can be realized.

In order to conduct the research correctly and get satisfactorily stable results, in the sense of sampling error, it is necessary to include a satisfactory number of examinees into the sample. The size of the sample for the research of this type is as well conditioned by the aims and tasks of the research, the size of the population and the degree of variability of the applied system of parameters.[25]

Based on the selected statistical-mathematical model and the aim of the research, the sample of examinees included 131 female dancers and 136 male dancers, aged from 11 to 13, actively involved in standard and Latin American dances in the Serbian dancing clubs.

The size of the so defined sample should satisfy the following criteria:

- the effectives of the sample should be planned so that it enables as many degrees of freedom as necessary for any coefficient in a pattern or correlation matrix, which is equal to or bigger than 0.22, to be considered different from zero with an inference error less than 0.01.
- in order to successfully apply the adequate statistical methods based on the latest convictions, the number of subjects in the sample must be five times bigger than the number of the applied variables.

During all the factor procedures, it should always be kept in mind that the results of the analysis depend on three major systems which determine the selec-

25 Popović, D.: Determining the structure of psychosomatic dimensions in fights and developing the procedures for their evaluation and monitoring - The Monograph, the Faculty of Physical Education, University of Priština, Priština, 1993.

tion and transformation of information: the sample of variables, sample of examinees, and the selected extraction, that is, rotational, method.[26]

2. 1. 1. The sample of variables of musical abilities

The evaluation of musical abilities has been accomplished on the basis of the well-known Seashore test battery that estimates musicality. This test lasts for 30 minutes and it consists of 6 groups of tasks that are listened to from an audiotape, and the answers are noted on the answer sheets prepared for that purpose. Auditory is provided by the regular schedule of the sound system and their volume so that all the examinees could be exposed to equal experimental conditions.

This test estimates the following dimensions:

- Pitch discrimination test: it consists of five columns, and each column contains ten tasks. For each task two tones are played. An examinee is to determine whether the second tone was higher or lower than the first one.
- Tone intensity discrimination test: it consists of five columns. Each column contains ten tasks. For each task two tones are played. An examinee is to determine whether the second tone was louder or quieter than the first one.
- Rhythm recognition test: it consists of three columns. Each column contains ten tasks. For each task two rhythmical structures are played. An examinee is to determine whether the second rhythmical structure was the same or different from the first one.
- Tone duration discrimination test: it consists of five columns.Each column contains ten tasks. For each task two tones of different duration are played. An examinee is to determine whether the second tone was longer or shorter than the first one.
- Timbre discrimination test: it consists of five columns, and each column contains ten tasks. For each task two tones are played. An examinee is to determine whether the second tone was the same or different from the first one.

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26 Popović, D.: Determining the structure of psychosomatic dimensions in fights and developing the procedures for their evaluation and monitoring - The Monograph, the Faculty of Physical Education, University of Priština, Priština, 1993.

- Tonal memory test: it consists of three columns. Each column contains ten tasks. On the column A for each task two melodies are played three times. On the column B two melodies of four tones are played, and on the column C two melodies of five tones are played. An examinee is to determine for each task in which tone the second played melody differs from the first one. For the column A: the first, second or third tones, for the column B: the first, second, third or fourth tones and for the column C: the first, second, third, fourth or fifth tones.

The evaluation is carried out so that each correct answer for each task in all the tests is worth one point. The total sum of points scored in particular tasks of each test separately constitutes the result. The result expressed in points should be converted to percentages. The female examinees, according to the number of points obtained on particular tests, depending on their age, are classified in certain classes from "A" to "E".

2. 1. 2. The sample of cognitive variables

For estimating intellectual dimensions the measuring instruments are selected so that the cybernetic model may be covered, paying attention to the fact that the selected tests can measure three types of the cognitive processing.

For estimating the efficiency of an input processor, respectively the perceptual reasoning, this test has been selected:

IT-1: test for matching the drawings designed for the evaluation of the perceptual identification and discrimination. The test consists of 30 tasks, and the test execution time is limited to 4 minutes. The analysis of the test has revealed that the difficulty of the tasks and their intercorrelation indicate that this is a typical speed test.

For estimating the efficiency of a parallel processor, or identification of relations and correlates, the following measuring instrument has been selected:

S-l: spatial reasoning test is designed for the evaluation of rapid simultaneous eduction of spatial relations. It consists of 30 tasks, where it should be determined which of the 4 transversal projections of the brick cluster corresponds to the specified picture of the brick cluster. The test execution time is 10 minutes.

For estimating the efficiency of a serial processor, or symbolic reasoning, the following measuring instrument has been selected:

AL-4: synonym-antonym test is designed for the evaluation of identification of the denotative meaning of the verbal symbols. It consists of 40 tasks of double-choice format. The test execution time is 2 minutes, therefore this test

belongs to the category of speed tests. The first main subject to measure is defined mostly by the tasks from the second half of the test and interpreted as the ability of rapid identification of the denotative meaning of the verbal symbols.

2. 2. The methods of data processing

All the data collected in this research were processed in the Multidiscipline Research Centre of the Faculty of Sports and Physical Education, the University of Priština, supported by the system of data processing programs developed by D. Popović, 1980, 1993, K. Momirović and D. Popović 2003.

The method for asymmetry-based overlap analysis proposed in this work is based on the previosly published work of Momirović, Štalec and Zakrajšek (1973) on the generalised image transformations and on the method for decomposition of latent structures proposed by Dobrić, Karaman and Momirović (1983). The essence of the proposed method is canonical covariance analysis (Momirović, Dobrić i Karaman, 1983) of one set of variables and image transformation of that set of variables performed by the projection of that set into the space stretched by the vectors of some other set of variables. Although the aim of the proposed method, in a certain sense, is similar to the aim of the classical method for the overlap analysis (Van Den Wollenberg, 1977) and method for canonical factor overlap analysis (De Sarbo, 1981), a criterion function of canonical covariance analysis in a generalised image space is different from the criterion function of Van Den Wollenberg and De Sarb's method, thus the interpretation of the obtained measures of association is based on completely different assumptions.

THE ALGORITHM

Let Z_1 be a data matrix, in the standard normal form, obtained by the description of a random sample E from n objects on the sample V_1 of m_1 quantitative or quantified variables, and let Z_2 be another data matrix, also in the standard normal form, obtained by the description of E on the sample V_2 of quantitative or quantified variables that $V_1 \cap V_2 = 0$. Assume, without losing the possibility of generalisation, $m_2 \leq m_1$, and denote by $R_{11} = Z_1^tZ_1$ and $R_{22} = Z_2^tZ_2$ the intercorrelation matrices, estimated under the maximum likelihood criterion, of the variables from V_1 and V_2, and by $R_{12} = R_{21}^t = Z_1^tZ_2$ the matrix of crosscorrelations between the variables from V_1 and V_2.

Let $B = R_{11}^{-1}R_{12}$ be a matrix of the standardized regression coefficients obtained by resolving the regression problem $Z_1B = Z_2 - E \mid \text{trag}\,(E^tE) = \text{minimum}$, and let $G = Z_1B$ be a matrix of the image variables from V_2 in the space stretched

by the vectors of variables V_1. Denote, finally, by $M = G^tG = B^tR_{11}B$ as a covariance matrix of variables from G.

The canonical covariance analysis in a generalised covariance image space may be defined as a solution of the problem

$$Z_2x_p = k_p,\ Gy_p = l_p \mid c_p = k_p{}^tl_p = \text{maximum},\ x_p{}^tx_q = y_p{}^ty_q = \delta_{pq}$$

where δ_{pq} are the Kroneker symbols. The covariances

$$c_p = k_p{}^tl_p = x_p{}^tMy_p$$

among the linear combinations of variables from Z_2 and linear combinations of variables from G can be maximized by the maximization of the function

$$f(x_p, y_p, \lambda_p, \eta_p) = x_p{}^tMy_p - 1/2\ \lambda_p\ (x_p{}^tx_p - 1) - 1/2\ \eta_p\ (y_p{}^ty_p - 1)$$

$$p = 1,...,m2$$

where λ_p and η_p are some unknown Lagrange multipliers.

Differentiation of the function f in regard to the elements of the vector x_p and then in regard to the elements of the vector y_p provides, for p = 1,

$$\partial f/\partial x_p = My_p - \lambda_p x_p \Rightarrow My_p = \lambda_p x_p$$

$$\partial f/\partial y_p = Mx_p - \eta_p y_p \Rightarrow Mx_p = \eta_p y_p$$

so that, by multiplying the first result by $x_p{}^t$, and the second result by $y_p{}^t$,

$$x_p{}^tMy_p = \lambda_p,\ y_p{}^tMx_p = \eta_p \Rightarrow \lambda_p = \eta_p = c_p$$

is obtained and, since $M^t = M$, $x_p = y_p$ and the problem is reduced to the simple problem of the characteristic values and the vector of the matrix M

$$(M - \lambda_p I)x_p = 0$$

$$p = 1,...,m2,$$

basically, to the problem of the principal components of the variables from G.

Let now $\delta^2 = (\text{trag } M)/m^2$ be a generalised canonical index defined on the relations between the variables from Z_1 and Z_2. A rational procedure for determining the number of significant latent dimensions, which are the generators of the relations between the analyzed sets of variables, is the well-known MEIG criterion, defined by

$$k = \text{num}\ (\lambda_p \geq \delta^2).$$

If $X = (x_p)$; p = 1,...,k is a matrix of eigenvectors associated with the significant latent dimensions, and $C = (c_p)$; p = 1,...,k is a diagonal matrix of the first k

covariances between the variables k_p and l_p, the latent dimensions obtained by the linear combinations of variables from Z_2 will be the vectors of the matrix

$$K = Z_2X,$$

the latent dimensions obtained by the linear combinations of variables from G will be the vectors of the matrix

$$L = GX,$$

and

$$C = K^tL = X^tMX$$

will be the matrix of covariances between the variables from K and L, and, simultaneously, the matrix of covariances of the variables from L, because, obviously,

$$C = L^tL = X^tMX.$$

Accordingly, the variables from K and L form one semibiorthogonal system, since

$$V = K^tK = X^tR_{22}X$$

is not, in a general case, a diagonal matrix.

Let D^2 = diag V be a variance matrix of variables from K. Therefore, the diagonal elements of the matrix

$$P = D^{-1}K^tLC^{-1/2} = D^{-1}C^{1/2} = (\rho_p)$$

will be quasicanonical correlations between the significant latent dimensions of variables from Z_2 and image variables from G.

Asymptotic variances of quasicanonical correlations ρ_p are, naturally,

$$\sigma_p^2 = (1 - \rho_p^2)^2 / n,$$

thus equal to the asymptotic variances of product-moment coefficient of any type of correlation. This fact may be used for the construction of approximate intervals of reliability and testing the hypothesis H_p: $\rho_p = \rho_{ph}$, where ρ_{ph} are hypothetical quasicanonical correlation coefficients.

Identification of the content of latent dimensions from L is very simple since, because of orthogonality of those dimensions both in the space of objects and in the space of variables from G, the matrix

$$S = G^tL = XC$$

is, concurrently, a pattern matrix and a structure matrix of nonstandardized latent dimensions, and the matrix

$$T = G^tLC^{-1/2} = XC^{1/2}$$

is a factor matrix of the matrix M.

Identification of the content of latent dimensions K is slightly more complicated, since

$$W = D^{-1}VD^{-1},$$

the intercorelation matrix of the variables from K, is not, in a general case, a diagonal matrix. The structure matrix, in the space of standardized latent dimensions, is

$$F = Z_2{}^tKD^{-1} = R_{22}XD^{-1}$$

so that, in the same space,

$$A = FW^{-1} = R_{22}X(X^tR_{22}X)^{-1}D$$

is a pattern matrix of variables Z_2; note that A and F are factor matrices of the matrix R_{22}, because

$$AF^t = R_{22}X(X^tR_{22}X)^{-1}X^tR_{22}$$

which is the proof that variables from K are the factors, in the factor-analytical sense, of the variables Z_2.

3. Results and discussion

By canonical covariance analysis (Momirović, Dobrić and Karaman, 1983), there have been determined the relations between the sets of variables for estimating musical and intellectual abilities of female examinees actively engaged in Standard and Latin American dances.

In (table 1) cross-correlations of musical and intellectual variables are presented, (table 4) shows coefficients of canonical correlations, the square roots of the canonical equation and their significances, and in (tables 2 and 3) correlations of variables for estimating musical and intellectual abilities with canonical dimensions are presented.

By inspecting the cross-correlation matrix of musical and intellectual variables, it can be noticed that there has been obtained statistically significant relationship between the efficient processing of the input processor and the test for the evaluation of the pitch, volume and timbre of a tone. Also it may be observed that significant correlation between the efficiency of the serial processor and tests for the evaluation of the duration of a tone, rhythm, pitch, tonal memory and timbre of a tone have been obtained, as well as positive correlation between the

efficiency of the parallel processor and tests for estimating memory, duration of a tone and rhythm.

The analysis of characteristic roots indicates that the significant correlation for rejecting the null hypothesis is possible for two roots, which means that from three hypothetical possible canonical dimensions, two are sufficient to explain the relations between two examined systems of variables (table 4).

In the space of musical abilities (table 2) the first canonical factor is defined as having a negative sign by the tests for evaluation of tonal memory, tone duration and rhythm. The correspondence factor in the space of intellectual abilities is defined by the tests for evaluation of parallel processor and of the efficiency of serial processing.

From all of the above stated, it necessarily follows that in this sport discipline, the ability to memorize music layouts, recognize the rhythm and duration of tones are directly related to the efficiency of the parallel and serial processors, and the ability to determine the pitch and timbre of tones is somehow connected with the input processor. It is also necessary to known that auditory sensitivity depends on the tone volume but concurrently on the pitch of a tone. Auditory sensitivity is greater with high than deep tones so it seems that a higher tone is stronger than a deep tone of the same acoustic intensity.

On the other hand, auditory sensitivity does not increase equally as volume. The strongest sense of a tone is about 30 times stronger than the weakest.

The second canonical factor in the space of musical abilities is best defined by the test for recognizing the pitch and timbre of a tone.

The correspondence factor in the space of cognitive abilities, is defined only by the test for estimating the efficiency of the input processor.

The analysis of both canonical dimensions leads to the conclusion that the input processor and the abilities to discriminate pitches may probably be subordinated to a common regulatory mechanism which coordinates the functioning of those two abilities. If all the previously obtained information is summarized, it could be concluded the following:

Spatial or simultaneous integration of information related to the rhythmic figures (or beyond the rhythmic structures) doubtlessly includes the eduction factor, meaning that there are relations between the elements of dance structures and the elements of rhythmic structures as well as there is some regularity which regulates the whole process of thinking regarding rhythmic tasks or problems.

However, since simultaneous information integration almost never appears independently, because most of the problems cannot be resolved in only one manner, that is simultaneously or serially. The information, and therefore rhythmic information of the dancers, also processed in time-structured series, thus serial

and successive processing, evaluated by verbal and numerical tests, significantly influence the reception, retention and processing of rhythmic operations.

The connection of input processors with musical abilities of dancers should also be emphasized.

CROSSCORRELATIONS BETWEEN VARIABLES OF MUSICALITY AND COGNITIVE ABILITIES OF DANCERS

Table 1.

TEST	IT1	AL4	SI
VIT	.33	.33	.03
JAT	.26	-.04	-.07
RIT	.08	.36	.31
DUT	-.02	.37	.39
BOT	.14	.27	.10
MEM	-.03	.28	.57

FACTOR STRUCTURE OF MUSICALITY VARIABLES

Table 2.

TEST	CAN1	CAN2
VIT	-.19	-.85
JAT	.19	-.39
RIT	-.61	-.24
DUT	-.73	-.00
BOT	-.28	-.44
MEM	-.84	.29

FACTOR STRUCTURE OF INTELLECTUAL VARIABLES

Table 3.

TEST	CAN1	CAN2
IT1	-.01	-.71
AL4	-.69	-.63
SI	-.84	.27

CANONICAL VARIABLES

Table 4.

R	R-sqr.	Chi-sqr.	df	p	A
.68	.47	123.48	18	.00	.47
.48	.23	45.93	10	.00	.77

4. Conclusion

The research was conducted in order to determine the relations between musical and intellectual abilities of the dancers engaged in the standard and Latin American dance.

For estimating relations between musical and intellectual abilities, 267 dancers, aged from 11 to 13, actively engaged in standard and Latin American dances were involved.

For estimating musical abilities the well-known Seashore test battery for the evaluation of musicality was used. This battery evaluates the following tests: pitch discrimination test, tone volume discrimination test, rhythm recognition test, tone duration discrimination test, timbre discrimination test and a tonal memory test.

For the evaluation of cognitive abilities, three measuring instruments were applied, selected so that the structure analysis could be solved on the basis of the cybernetic model of Das, Kirby and Jarman, respectively Momirović, Bosnar and Horge 1982, taking into account the fact that the chosen tests measure three types of intellectual processing.

For estimating the efficiency of the perception processor, test IT-1 was selected; for estimating the efficiency of the serial processor, test AL-4; and for estimating the efficiency of the parallel processor, test S-1.

All the data collected in this research were processed in the Multidiscipline Research Centre of the Faculty of Sports and Physical Education, the University of Priština, supported by the system of data processing programmes developed by D. Popović, 1980, 1993, K. Momirović and D. Popović 2003. The canonical correlation analysis determined the correlations between the sets of variables for estimating musical and intellectual abilities of the examinees who are actively engaged in standard and Latin American dance. The analysis of characteristic roots points to the fact that the significant correlation for rejecting the null hypothesis

is possible only for two roots, which means that out of three hypothetic possible canonical dimensions two are sufficient for explaining the relations between the two examined systems of variables. In the space of musical abilities the first canonical factor is defined as having a negative sign by the test for estimating the tonal memory, the duration of tones, and rhythm. The correspondence factor in the space of intellectual abilities is defined by the test for estimating parallel and serial processing. The second canonical factor in the space of musical abilities is best defined by the test for recognition of pitches and for discrimination of the timbre of tones. The correspondence factor in the space of intellectual abilities is defined only by the test for evaluation of the efficiency of the input processor.

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Summary

The research was conducted in order to determine the relations between musical and intellectual abilities of the dancers occupied with the standard and Latin American dance. For estimating the relations between musical and intellectual abilities, 267 dancers, aged from 11 to 13 were involved. For estimating musical abilities the well-known Seashore test battery for the assessment of musicality was used. This battery evaluates the following tests: pitch discrimination test, tone intensity discrimination test, rhythm recognition test, tone duration discrimination test, timbre discrimination test and a tonal memory test. For the evaluation of cognitive abilities, three measuring instruments were applied, selected so that the structure analysis could be solved on the basis of the cybernetic model of Das, Kirby and Jarman, respectively Momirović, Bosnar and Horge 1982, taking into account the fact that the chosen tests measure three types of intellectual processing. For estimating the efficiency of the perception processor,

test IT-1 was selected; for estimating the efficiency of serial processor, test AL-4; and for estimating the efficiency of parallel processor, test S-1. All the data collected in this research were processed in the Multidiscipline Research Centre of the Faculty of Sports and Physical Education, the University of Priština, supported by the system of data processing programmes developed by D. Popović, 1980, 1993, K. Momirović and D. Popović 2003. The canonical correlation analysis determined the correlation between the sets of variables for estimating musical and intellectual abilities of the examinees who are actively engaged in standard and Latin American dance. The analysis of characteristic roots points to the fact that the significant correlation for rejecting the null hypothesis is possible only for two roots, which means that out of three hypothetic possible canonical dimensions two are sufficient for explaining the relations between the two examined systems of variables. In the space of musical abilities the first canonical factor is defined as having a negative sign by the test for estimating tonal memory, tone duration and rhythm. The correspondence factor in the space of intellectual abilities is defined by the test for estimating parallel and serial processing. The second canonical factor in the space of musical abilities is best defined by the test for pitch recognition and for determining the timbre. The correspondence factor in the space of intellectual abilities is defined only by the test for the assessment of efficiency of the input processor.

Key words: /input processor/pitch/timbre/tone duration/analysis/tonal memory/root/hypothesis/

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